



Agile Software Development on a DARPA Project

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Outline



- Background
- DARPA System F6 Program
- Agile Software Development
- Lessons Learned
- Agile in Aerospace: Issues and Opportunities

Emergent Overview



■ Small Business

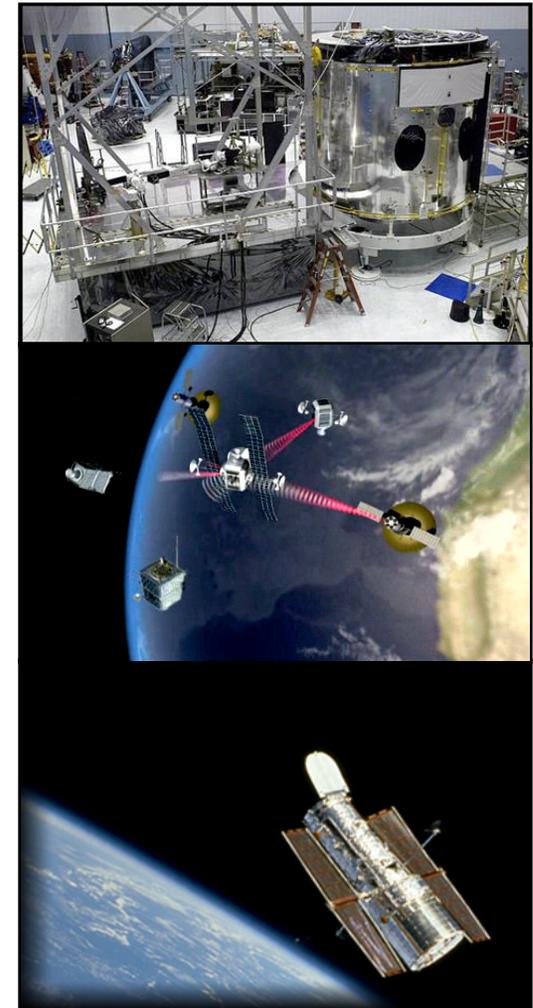
- Headquartered in Greenbelt, MD; Offices in Austin, TX; Denver, CO; Albuquerque, NM and Mountain View, CA
- 60 employees
- 20% B.S., 60% M.S., 20% Ph.D.
- CMMI Maturity Level 3

■ Core Capabilities

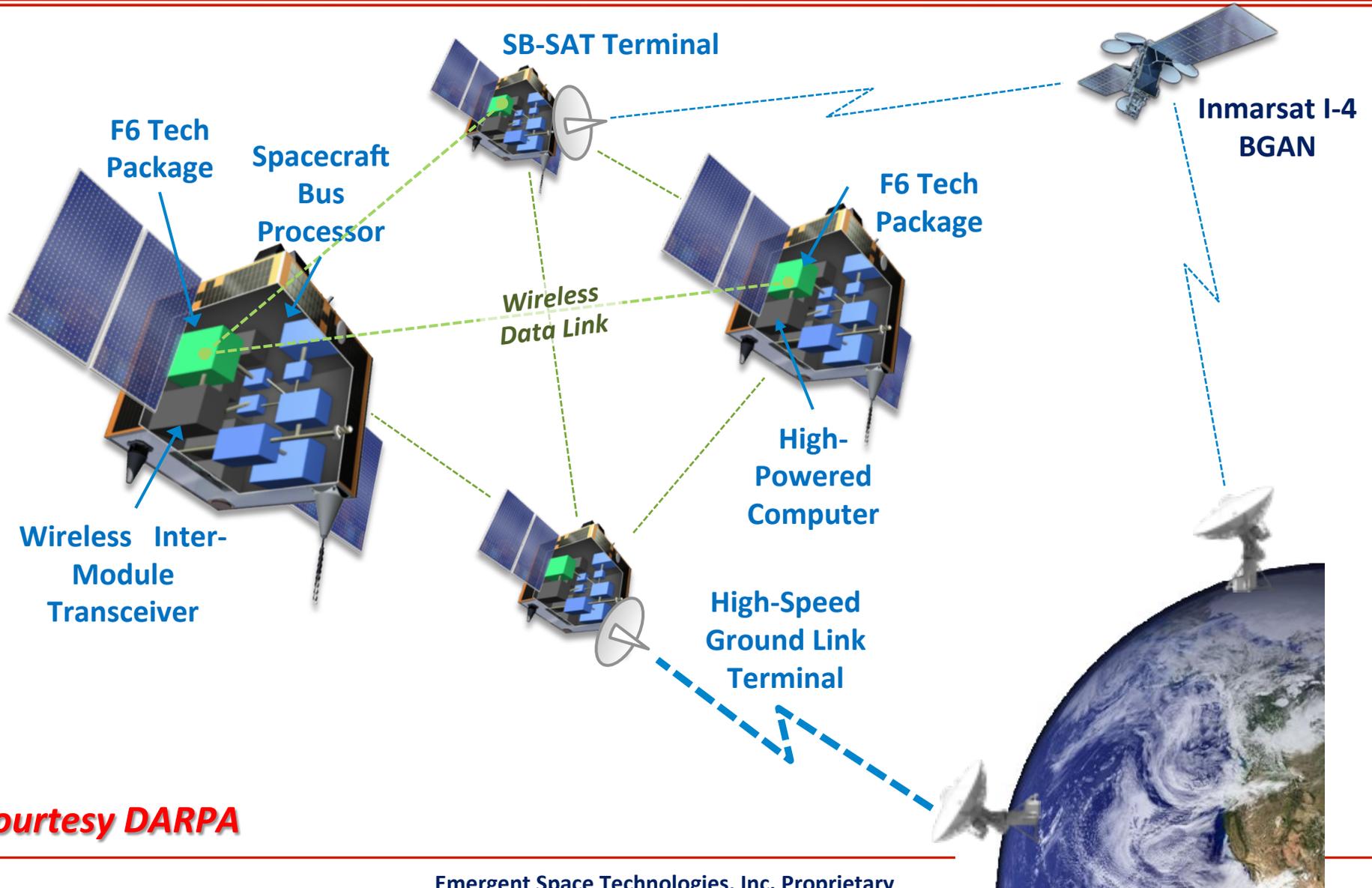
- Systems Engineering and Integration
- Guidance, Navigation & Control
- Flight Dynamics
- Global Navigation Satellite Systems (GPS, Galileo)
- Flight and Ground Software
- Research and Technology Development

■ Key Differentiators

- Leadership Team is highly technical, hands-on and mission-focused
- Key personnel are industry-leading experts in systems engineering, GN&C, GPS, flight dynamics and software development



Notional System F6 On-Orbit Demo

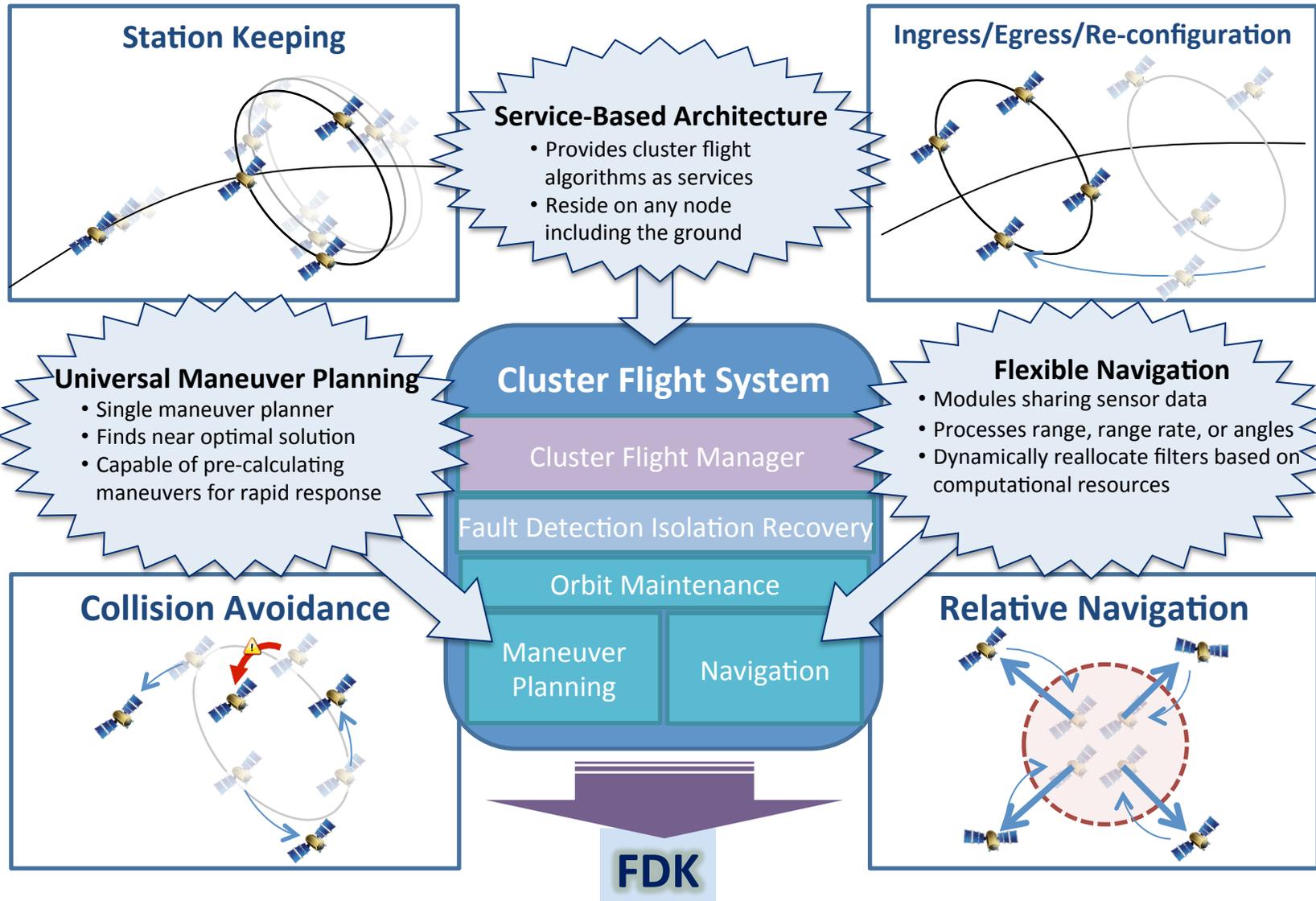


Courtesy DARPA

Key System F6 Program Artifacts

- **F6 Developer's Kit (FDK)**—everything needed for an independent 3rd party to develop a module that can fully participate in a fractionated cluster
 - Interface standards, network protocols, software, behaviors/rules
 - Freely distributed under an open source license, freely exportable
 - Three core components:
 - Wireless Inter-Module Communication (WIC)
 - Information Architecture (IA)
 - Cluster Flight Application (CFA)
- **F6 Technology Package (F6TP)**—physical instantiation of the FDK to enable a spacecraft to become a cluster module
 - Executes protocol stack, middleware, cluster flight software
 - Interfaces to WIC, F6 payloads and spacecraft bus
 - Multiple sources, capable of supporting multiple spacecraft bus types
 - Goal is for the F6TP to become a COTS product

Emergent's Cluster Flight Solution

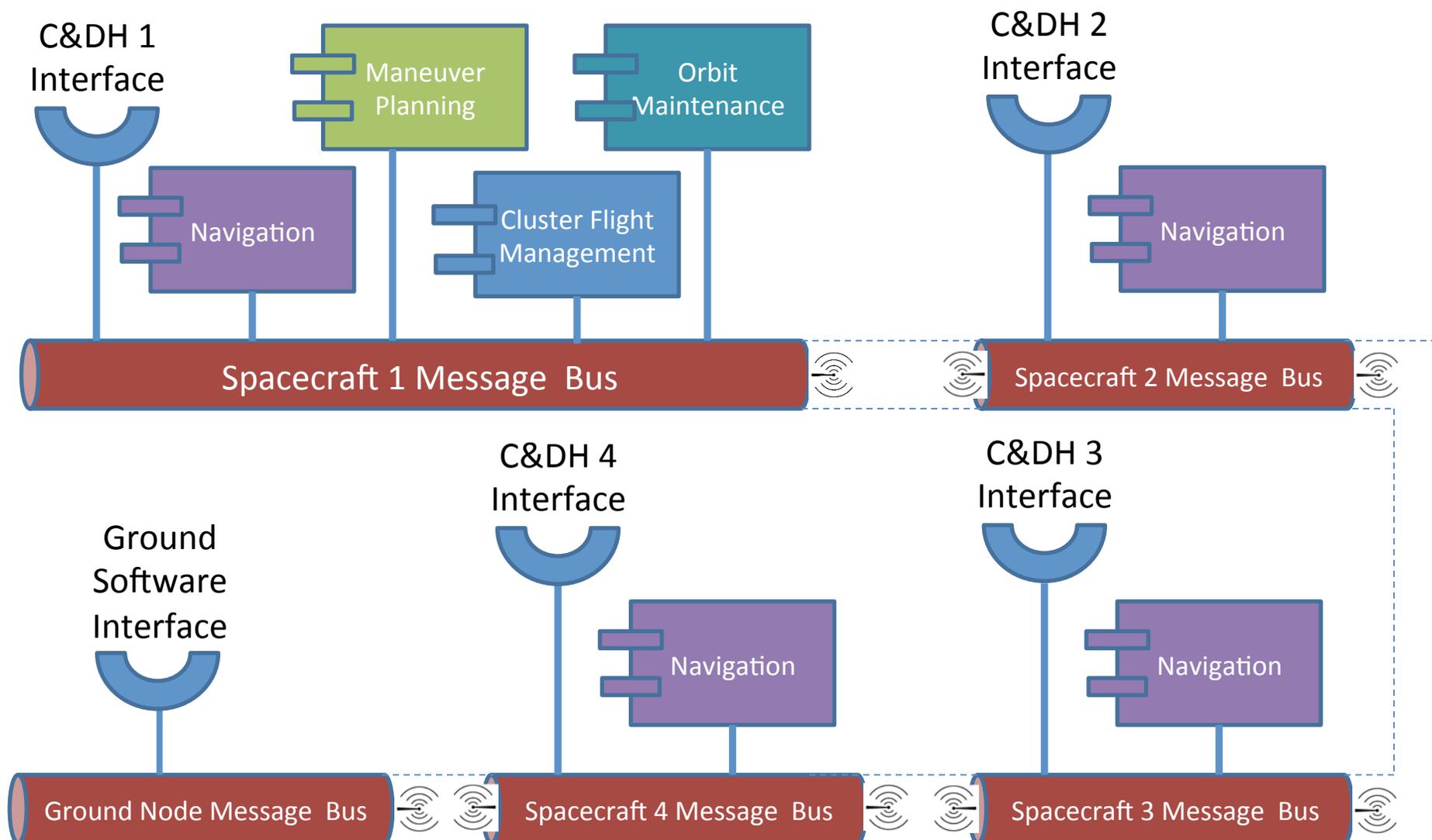


F6 Cluster Flight Application (CFA)



- **Distributed “app” for multi-spacecraft GN&C**
 - Cluster formation, ingress and egress
 - Station-keeping
 - Scatter/re-gather
- **Service-based architecture**
 - Message-oriented Middleware
- **Model-based software development**
 - Matlab/C/C++
 - Matlab autocoder
- **Implemented on GSFC’s core flight executive (cFE)**

4-Spacecraft CFA Deployment



Why Software Projects Fail

Among the most common factors:

- Unrealistic or unarticulated project goals
- Inability to handle the project's complexity
- Poor communication among customers, developers and users
- Inaccurate estimates of needed resources
- Badly defined system requirements
- Poor reporting of project status
- Unmanaged risks
- Use of immature technology
- Sloppy development practices
- Poor project management
- Stakeholder politics
- Commercial pressures



Agile Software Development



- **A software development methodology based on iterative and incremental development**
 - Stresses building and maintaining a working product from the earliest possible time
 - Develops software functionality in small increments that are added to the working product as you go along
 - Incorporates V&V into the process early, preventing end-game V&V
 - Implements a “divide and conquer” strategy for breaking up large problems into manageable pieces
- **Agile attributes**
 - Individuals and interactions over processes
 - Working software over comprehensive documentation
 - Customer collaboration over contract negotiation
 - Responding to change over rigidly following a plan
- **Agile approaches**
 - Extreme Programming, Kanban, Lean Software, Scrum

The Scrum Framework

- **Scrum is a *framework* for carrying out agile software development**
- **Regular stand-up meetings**
 - What have you accomplished since last time?
 - What do you plan to do accomplish this time?
 - Is anything holding you up?
- **Centered on the team, focused on the customer**
 - Customer and inter-team collaboration is required
 - Team is given real responsibility/authority
- **Planning is important, but adapting to change is more important**
 - Recognition and responsiveness to requirements changes
- **Short software iterations or “sprints” deliver functionality early and often**



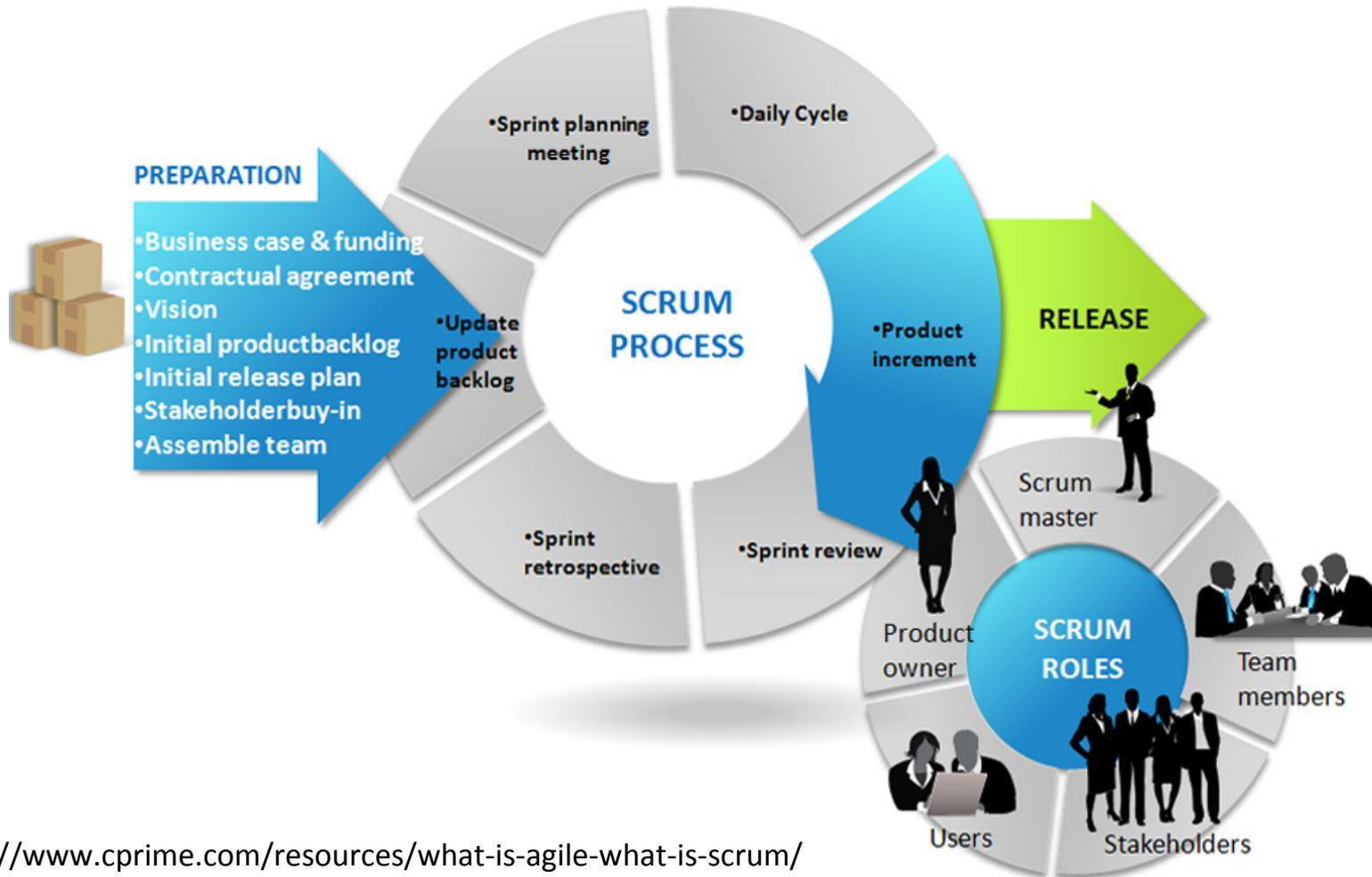
The Scrum Process



- **A product owner creates a prioritized “wish list” or product backlog**
 - This is coordinated with the other teams involved
- **During sprint planning, the team selects a subset of features to implement from the product backlog**
- **The team has a set amount of time — the sprint — to complete its work (usually three weeks)**
 - Progress is reviewed each day at the daily Scrum
 - The Scrum Master keeps the team focused on its goal
 - At the end of the sprint, the software should be ready to show to a customer or stakeholder
 - The sprint ends with a sprint review and retrospective
- **The next sprint begins with the team selecting another subset of features and then repeating the cycle**

Agile is Iterative

SCRUM PROCESS



<https://www.cprime.com/resources/what-is-agile-what-is-scrum/>

User Stories



- **A requirements description technique to drive the software development process**
 - Short, simple descriptions features told from the user's perspective
 - Help maintain the focus on the customer
- **Good User Stories takes the form:**
 - As a [role], I want [some goal] so that [some reason]
 - “As a thermal engineer, I want to monitor instrument temperatures so that I can heat (or cool) the instrument”
 - Includes the success criteria
 - May evolve over time
- **Writing User Stories is a learned technique**
 - Estimating tasks for User Stories is also a learned technique

The Product Backlog



ToDo List

ID	Story	Estimation	Priority
7	As an unauthorized User I want to create a new account	3	1
1	As an unauthorized User I want to login	1	2
10	As an authorized User I want to logout	1	3
9	Create script to purge database	1	4
2	As an authorized User I want to see the list of items so that I can select one	2	5
4	As an authorized User I want to add a new item so that it appears in the list	5	6
3	As an authorized User I want to delete the selected item	2	7
5	As an authorized User I want to edit the selected item	5	8
6	As an authorized User I want to set a reminder for a selected item so that I am reminded when item is due	8	9
8	As an administrator I want to see the list of accounts on login	2	10
Total		30	

Example Sprint Schedule



ID	Task Name	Duration	Nov 3, '13							Nov 10, '13							Nov 17, '13						
			S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
1	Sprint Development	14 days	[Gantt bar from Nov 3 to Nov 17]																				
2	Iteration Kickoff Meeting	0 days	◆ 11/4																				
3	CM Planning	0 days	◆ 11/4																				
4	Team Scrum	0 days	◆ 11/6																				
5	Team Scrum	0 days	◆ 11/8																				
6	CM Planning	0 days	◆ 11/11																				
7	Team Scrum	0 days	◆ 11/11																				
8	Team Scrum	0 days	◆ 11/13																				
9	Team Scrum	0 days	◆ 11/15																				
10	CM Planning	0 days	◆ 11/18																				
11	Team Scrum	0 days	◆ 11/18																				
12	Team Scrum	0 days	◆ 11/20																				
13	Iteration Review	0 days	◆ 11/22																				
14	Iteration Pre-planning	2 days	[Gantt bar from Nov 20 to Nov 22]																				
15	Pre-planning	0 days	◆ 11/20																				
16	Iteration Objectives	0 days	◆ 11/22																				

Managing the Scrum Process



Story	To Do	In Process	To Verify	Done
<p>As a user, I... 8 points</p>	<p>Code the... 9</p> <p>Code the... 2</p> <p>Test the... 8</p> <p>Test the... 4</p>	<p>Code the... DC 4</p> <p>Test the... SC 8</p>	<p>Test the... SC 6</p>	<p>Code the... D</p> <p>Test the... SC 8</p> <p>Test the... SC</p> <p>Test the... SC</p> <p>Test the... SC 6</p>
<p>As a user, I... 5 points</p>	<p>Code the... 8</p> <p>Code the... 4</p> <p>Test the... 8</p> <p>Code the... 6</p>	<p>Code the... DC 8</p>		<p>Test the... SC</p> <p>Test the... SC</p> <p>Test the... SC 6</p>

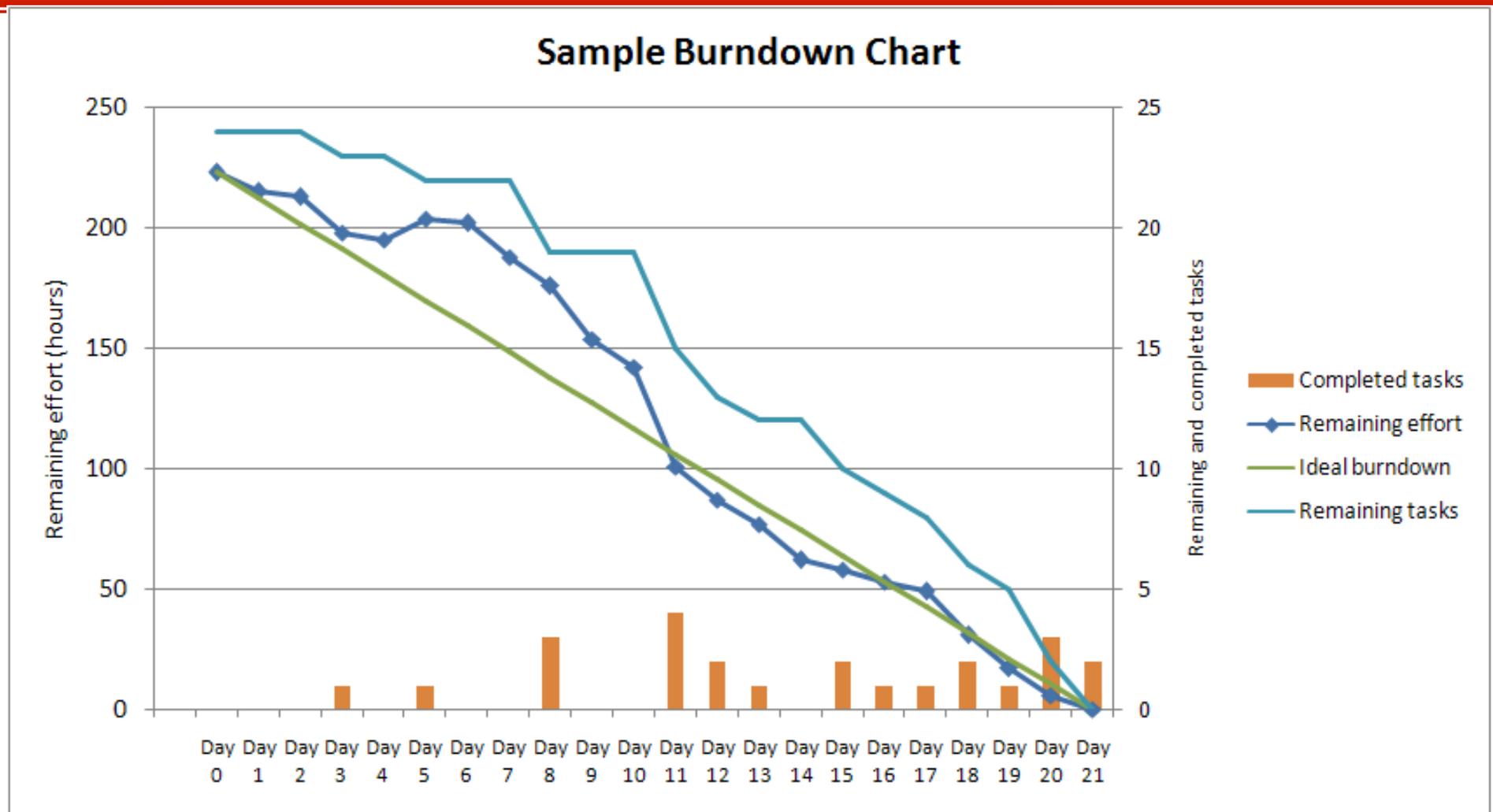
Virtual Planning Board



• 1.1		Select All	Unselect All	Summaries	Cards	List		
GB-224	Import/Export - file formats are different across vivariums			1.1				
GB-280	xenograft passages not properly refreshed during mass subject registration			1.1-Iter1			0	
GB-279	Mass Registration - Set 'Pilot' flag on mass registration			1.1-Iter1			0.5	
GB-142	Subject ID (tag#) - alphanumeric text field - provide a better sort for numbers			1.1-Iter1			1	
GB-277	App should display version/build info on screen			1.1-Iter1			1	
GB-278	Make sending email a configuration option			1.1-Iter1			0.5	
GB-285	Regimen Versions or Xenograft Passage - Java Error on selecting Edit			1.1-Iter1			0.5	
GB-294	error messages incorrect on observation import			1.1-Iter1			0.5	
GB-288	Change "Pilot" to be "Take Rate" and Yes/No as values			1.1-Iter1			1	
GB-287	Specimen: Change Fixative Types to be OCT and FPFE		+2 Subs	1.1-Iter1			3	
GB-289	Better highlight of fields in focus and buttons in focus			1.1-Iter1			0.5	
GB-284	User Account - Setting any Admin role brings up blank page on login			1.1-Iter1			0.5	
GB-180	Force usernames to lower case		+3 Subs	1.1-Iter1			0.5	
GB-270	Subject - List specimens list on subject detail form		3 Subs	1.1-Iter1			5	
GB-28	Deactivate a User		+3 Subs	1.1-Iter1			3	
GB-7	Search/Filter Registered Mice		+3 Subs	1.1-Iter2			8	
GB-97	Search/Filter Observations			1.1-Iter2			5	
GB-195	Filter Specimens List			1.1-Iter2			5	
GB-222	Import Mayo's StudyLog Data			1.1			13	
GB-188	Create a Survival Rate Graph in Glassbox			1.1			3	
GB-187	Report: Export Survival Rate Data Report			1.1			3	
GB-220	Import TGen StudyLog Data			1.1			8	
GB-267	Report: Provide consortium study data by regimen for use by Pharma Companies			1.1			3	
GB-269	Report: Observations Log (weights)			1.1			5	
GB-31	Create New Regimen		+3 Subs	1.1			2	
GB-231	Manage Xenografts			1.1			3	

Versions	Manage
<p>Unscheduled</p> <p>1.0</p> <p>1.0.2</p> <p>1.0.3</p> <p>1.1</p> <p>Master: None Release date: None Bug: 4 Improvement: 9 Risk: 1</p> <p>Sub-task: 14 User Story: 12</p> <p>Unresolved: 30 Resolved: 10</p> <p>To Do: 27 In Progress: 3 Done: 10</p> <p>T. issues: 40 T. estimate: 1 day T. spent: 0 minutes T. remaining: 1 day Points: 75.5</p> <p>Release Pending Issues</p> <p>1.1-Iter1</p> <p>Master: 1.1 Release date: 16/Jan/09 Bug: 4 Improvement: 9</p> <p>Sub-task: 11 User Story: 1</p> <p>Unresolved: 15 Resolved: 10</p> <p>To Do: 10 In Progress: 5 Done: 10</p> <p>T. issues: 25 T. estimate: 0 minutes T. spent: 0 minutes T. remaining: 0 minutes Points: 17.5</p>	

Burndown Chart

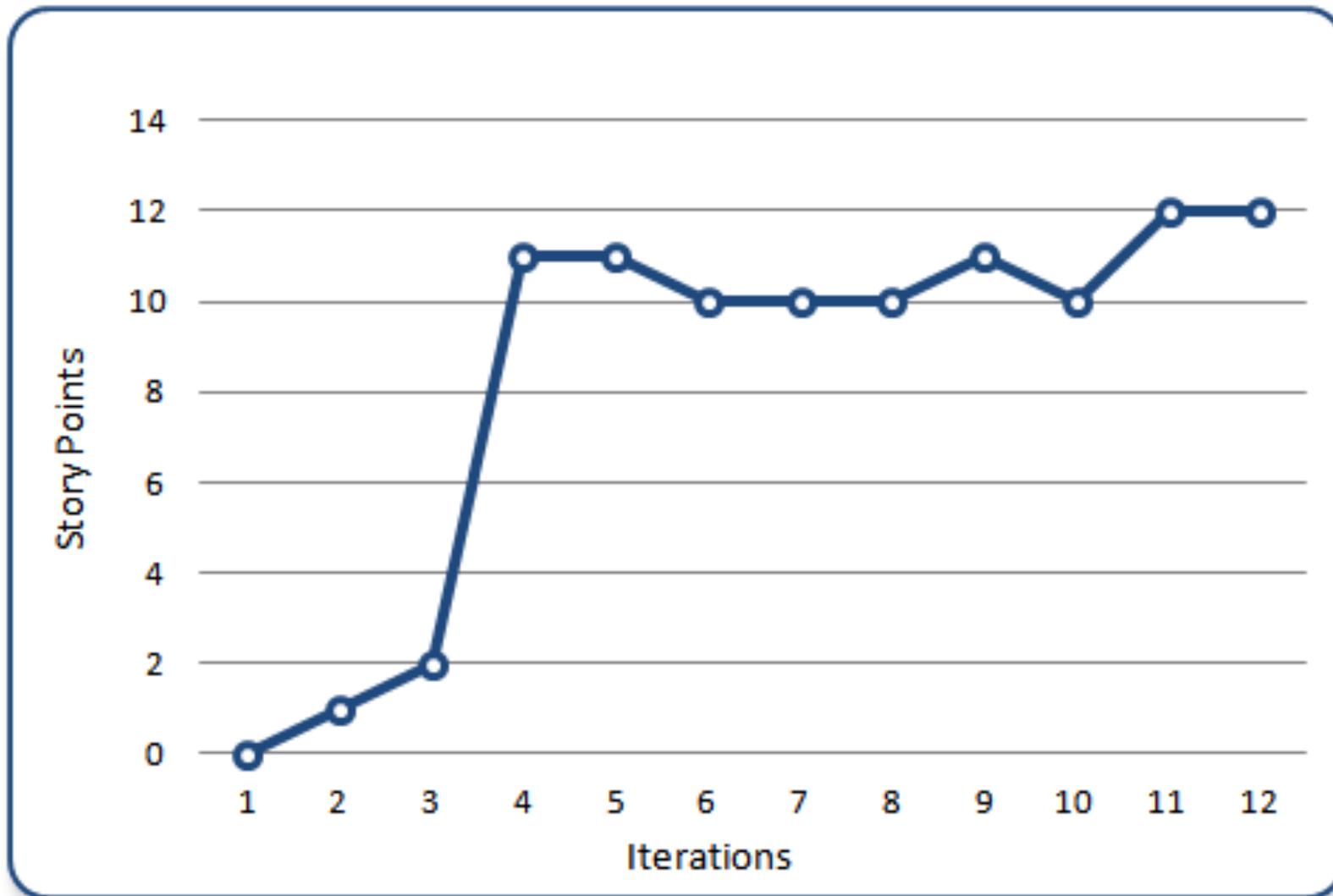


Story Points



- **A measure used by Scrum teams to estimate of the effort to implement a Story**
 - Some teams use a relative scale based on the Fibonacci series, e.g. 1, 2, 3, 5, 8, 13, 21, 34, 45, ...
 - Not directly related to time, e.g., hours, days, weeks, etc.
- **Story points are used to calculate team velocity**
 - It provides a simple method for measuring the rate at which scrum teams deliver software
 - Velocity is the sum of the estimates of delivered features per iteration
 - Within a short time, velocity stabilizes and provides a basis for improving the accuracy and reliability of planning of agile software projects

Team Velocity Chart



Matlab Source Code/Coder-Generated C



CFA Service	Number of Matlab files	Comment Lines	Source Matlab Lines	Coder Generated C Lines
MPS	82	7,535	15,988	24,846
NAV	134	9,413	13,763	41,168
OMS	7	4,543	13,829	14,300
utils	113	7,260	4,746	5,194
shared	11	329	103	--
TOTALS	347	29,138	48,438	85,508

❖ *Line counts derived using Perl script TLOC 1.60, developed by Northrop Grumman Corporation*

C++ Source Code



CFA Service	Number of C++ Classes	Comment Lines	Source Lines
MPS	21	7,211	5,695
CFM	9	5,116	8,014
NAV	11	3,656	7,781
OMS	7	4,238	3,645
MMS	2	522	656
shared	41	18,351	13,682
utils	7	2,161	4,374
TOTALS	91	41,255	43,847

- ❖ *Implementation of Adaptors and OS-specific source code could add approximately 46K TLOCs of development as per cFE hosting experience*

CFA Software Metrics



■ CFA on DIECAST

- DIECAST is an Emergent-developed surrogate for the F6 Operating System used for deterministic testing of the CFA
- 43,847 lines of C++ source code developed
- 48,438 lines of Matlab code developed
- 85,508 lines of Matlab Coder auto-generated C Code
- 70,393 comment lines added to C++ and Matlab code
- Completed in 25 months

■ CFA port to cFE

- 21,252 C/C++ source code developed
- 25,509 comment lines added to C/C++ Source Code
- Completed in 126 days

Emergent Lessons Learned



- **Find the right rhythm for the team**
 - 3-week sprints with 3 Scrums per week
- **Developers liked the process**
 - Training on the process is important
 - Continuously evaluate and evolve the process
- **Good tools improve team velocity**
 - Jira
 - Greenhopper
 - Coverity – Static and coverage analysis
 - Jenkins
- **Integrated build/unit test saved time and effort**
- **Model-based development saved time and effort**
- **Matlab Coder's advantages outweighed its disadvantages**
- **Proper configuration management is critical to success**

■ **Systems Engineering**

- Requirements can and will change after Phase C, so agile methods should apply well to space systems development
- User Stories do not fit the usual Requirements mold but they can be adapted to the jargon of the aerospace industry
 - Subsystem Engineers, Operators and Scientists are logical creators of User Stories
- Model-based software development supports requirements development *and* software development

■ **Software Engineering**

- Multiple product teams mean multiple scrums and they all must be coordinated → modern tools facilitate such communication

■ **Integration and Test**

- Subsystem components are typically outsourced and then integrated as they are delivered, delaying key I&T activities
- Build the test suite as you go along
- Evolve your test success criteria as the product evolves

Software Can be Better

“You’re looking at it wrong. You’re looking at it as a hardware person in a fragmented world. You’re looking at it as a hardware manufacturer that doesn’t really know much about software, who doesn’t think about an integrated product, but assumes the software will somehow take care of itself...And you assume that the software will somehow just come alive on this product that you’re dreaming of, but it won’t.”

-Steve Jobs, Oct. 2010

